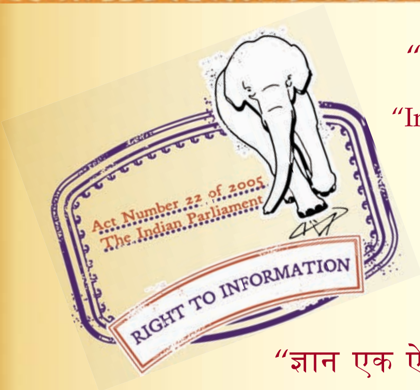
IS 7418 (1991): Criteria for design of spiral casing (concrete and steel) [WRD 15: Hydroelectric Power House Structures]



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भारतीय मानक

सर्पिल आवरक (कंक्रीट एवं इस्पात) के डिजाइन के लिए माप दण्ड का मसौदा

(पहला पुनरीक्षण)

Indian Standard

CRITERIA FOR DESIGN OF SPIRAL CASING (CONCRETE AND STEEL)

(First Revision)

UDC 621·224·2-758 : 621·311.21

BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

December **1991** **Price Group 3**

Hydroelectric Power House Structures Sectional Committee, RVD 15

FOREWORD

This Indian Standard (First Revision) was adopted by the Bureau of Indian Standards, after the draft finalized by the Hydroelectric Power House Structures Sectional Committee had been approved by the River Valley Division Council.

Spiral casing is a fixed, circumferential casing of a reaction turbine of gradually contracting cross-section. The spiral provides an axial symmetrical flow to the guide apparatus. The contraction of the cross-section of the spiral from point to point towards the tooth is gradual. The change in velocity would result in turbulence and increased losses.

No rigid design criteria can be drawn up for the spiral casing as the design depends upon the hydraulic features, such as head, runner profile and operational requirements. General recommendations are laid down in this standard for the purpose of guidance in design.

This standard was first published in 1974. This first revision has been made in view of the experience gained during the course of these years in the use of this standard. The important changes incorporated in this revision are as follows:

a) Definitions included under terminology have been modified to align them with IEC definitions.

b) Fig. 2 has been modified to give the relationship of *K* for different heads and different types of turbines used.

c) Corrosion allowance of 1 to 2 mm have been included.

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

Indian Standard

CRITERIA FOR DESIGN OF SPIRAL CASING (CONCRETE AND STEEL)

(First Revision)

1 SCOPE

This standard gives the criteria for design of concrete and steel spiral casing for reaction turbines.

2 REFERENCES

The Indian Standards listed in Annex A are necessary adjuncts to this standard.

3 TERMINOLOGY

3.0 For the purpose of this standard the definitions given in IS 4410 (Part 10) : 1988 and the following shall apply.

3.1 Angle of Envelopment

The angle in plan by which the spiral casing envelopes (or surrounds) the guide apparatus (*see* Fig. 1).

3.2 Head

3.2.1 *Pressure Head*

The head of water equivalent to the pressure at any point in the system.

3.2.2 *Velocity Head*

The head equivalent to the square of the mean velocity divided by twice the acceleration due to gravity.

3.2.3 *Potential Head*

Elevation of measuring point above mean sea level or other reference datum.

3.2.4 *Total Head*

The sum of potential head, pressure head and velocity head at a given section.

3.2.5 *Net Head*

The head available for doing work on the turbine; it is the difference between total head at inlet and outlet.

3.2.6 *Gross Head*

The difference in elevation between the water levels at the upstream and downstream limits of the installation when no water is flowing.

3.2.7 *Rated Head*

The net head acting on turbine for doing work while delivering rated output speed with guide vane fully open.

3.3 Design Pressure

The maximum pressure occurring in spiral case including water hammer under normal operating conditions.

3.4 Rated Discharge

Turbine discharge at rated head, rated output and rated speed with guide vane fully open.

3.5 Thrust Collar

The collar that is provided in the pipe, before the spiral casing, to take water thrust. The collar may be in the shape of a flange or thrust bracket.

3.6 Tooth

That part of spiral casing which separates the inlet of the spiral casing from its minimum section. The tooth replaces the last stay vane (*see* Fig. 1). It is also called nose.

4 CLASSIFICATION

4.1 Spiral casings may be classified on the following basis:

a) *Material of Construction*

  i) Concrete spiral casing

  ii) Steel spiral casing

b) *Angle of envelopment*

  i) Full spiral casing (spiral sector 315 degrees and above)

  ii) Partial spiral casing (spiral sector less than 315 degrees)

c) *Flow Conditions*

  i) Constant momentum of velocity

  ii) Constant velocity.

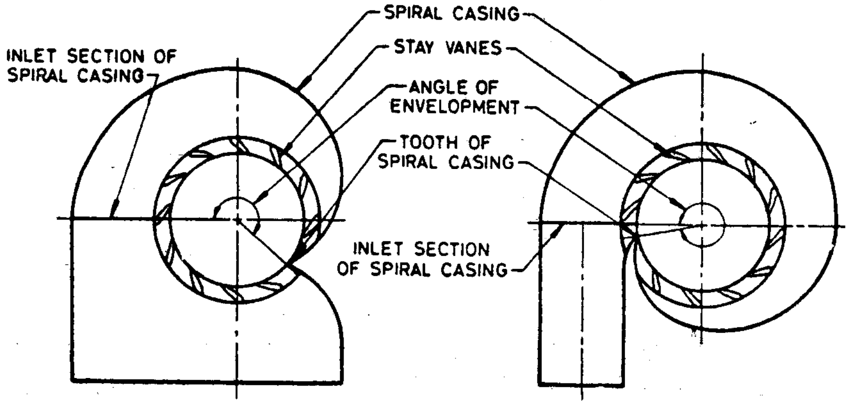

FIG. 1 SPIRAL CASING

5 LIMITING HEADS AND VELOCITIES

5.1 The selection or adoption of concrete or steel spiral casing depends upon the techno-economic considerations. The following gross heads may serve as guide for selecting the type of spiral casing:

a) *Concrete Spiral Casing* — Up to 40 m.

NOTE — Sometimes concrete spiral casing are used even for higher heads with thin steel linings (not designed to take loads).

b) *Steel Spiral Casing* — Above 30 m.

5.2 Velocity in the inlet section of the spiral casing, which may be taken as the design velocity, depends on the rated head and may be computed from the following formula:

$$V \leqslant K \sqrt{H}$$

where

V = design velocity, m/s;

K = coefficient, depending on rated head and type of turbine; and

H = rated head, m.

5.2.1 Value of K varies for diffierent heads and also on type of turbines used. The values of K for different values of head and different turbines used may be taken from Fig. 2.

5.2.2 Sometimes, the velocity inlet section is little higher than the design inlet velocity as the part of spiral casing near the inlet section is reduced in area due to other considerations, such as standard valve size, transport limitations and block width;

6 DATA FOR DESIGN

6.1 The following data should be collected for design of spiral casing:

a) Head — Gross maximum, minimum and rated;

b) Rated output;

c) Rated discharge;

d) Maximum pressure in spiral casing including water hammer; and

e) Maximum permissible velocities (in case of concrete spirals).

7 HYDRAULIC DESIGN

7.1 General

The meridinal sections of the spiral casing should provide uniform distribution of discharge around the circumference of the guide apparatus. The following equation satisfies the above conditions:

$$Q_i = \frac{U_i}{U} Q \quad \ldots \text{(1)}$$

where

Q_i = discharge through meridinal section of the spiral casing, in m³/s, at an angle of U_i;

U_i = angle of the meridinal to the initial plane passing through the tooth, in radians;

U = total angle of envelopment of spiral casing; and

Q = total discharge through the spiral casing, m³/s.

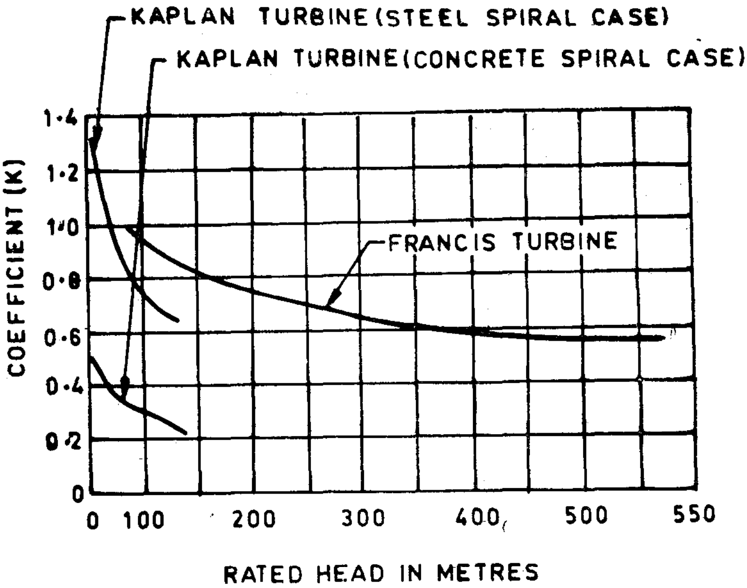

FIG. 2 VALUE OF CO-EFFICIENT 'D' FOR DIFFERENT RATED HEADS

7.2 Design

The hydraulic design of the spiral casing may be done by any one of the methods given in **7.2.1** and **7.2.2**.

7.2.1 Logarithmic spiral, in which the moment of velocity is kept constant, that is, where

$$V_u \cdot r = C \qquad \ldots . (2)$$

where

V_u = circumferential velocity, in m/s, at the point where radius is r;

r = radius, in m, of the spiral casing; and

C = constant.

Since, discharge Q_i through an infiniterstimal segment of width dr is given by $d\,Q_i = b\,(r)$. $Vu.\,dr$, where $b\,(r)$ is the height of the spiral as a function of radius r; by using equation (2).

$$Q_i = C \int_{r^1}^{r^2} \frac{b\,(r)}{r}\, dr \qquad \ldots . (3)$$

The spiral is designed by solving equation (3) with equation (1) at various meridinal sections of the spirals.

7.2.1.1 Logarithmic spiral provides an axi-symmetrical potential flow and is, therefore, characterized by irrotational free vertex flow. The circumferential velocity in this case will increase from the inlet section to the spiral tooth.

7.2.2 Constant velocity spiral, is where the circumferential velocity V_u is kept constant.

7.2.2.1 Constant velocity spiral has larger sections for the same inlet section as compared to the sections of the logarithmic spiral.

7.3 Selection of the type of spiral casing would be from the above two methods. The final optimized efficiency should be for best hydraulic efficiency as decided by engineer-in-charge.

8 CONCRETE SPIRAL CASING

8.1 General

Concrete spiral casings are generally used for low heads [*see* **5.1** (a)] and the allowable velocities are low. Where used for higher heads, steel liner should be provided to cater for high velocities and water-tightness. To keep the block width within limits, the concrete spiral casings do not normally envelope the guide apparatus fully and the angle of envelopment used is generally from 180° to 225°.

8.2 Shape

The sections of concrete spiral casings are generally of trapezoidal shapes because they are easier to form compared to circular or elliptical shapes.

8.2.1 Some of the trapezoidal shapes are shown in Fig. 3.

8.3 Materials and Stresses

The design and construction of spiral casing in concrete should generally conform to IS 456 : 1978, IS 1343 : 1980, IS 3370 (Part 1) : 1965, IS 3370 (Part 2) : 1965, IS 3370 (Part 3) : 1967 and IS 3370 (Part 4) : 1967.

8.4 Temperature and Shrinkage

The effect of temperature and shrinkage of concrete should be taken into account in the design of concrete spiral casing.

8.4.1 Shrinkage equivalent to 15° temperature drop and temperature change of ± 5° should be used for design unless otherwise specified by the engineer-in-charge.

8.4.2 Combined effect of shrinkage and temperature should be taken as 20° drop or 5°C rise in top part relative to the bottom slab.

8.4.3 In concrete structures, shrinkage results largely from temperature drop from the maximum temperature reached soon after placing to average annual temperature. Such temperatures may usually exceed 15°C. However, this value may be used taking into consideration procedures to minimize temperature effect by jointing and by adopting placing schedule of concrete as given **8.6**.

8.5 Structural Design

The spiral casing may be subjected to the following loads and stresses:

a) Maximum internal pressure including water hammer,
b) Load due to maximum tail water (with no water inside),
c) Stresses due to temperature and shrinkage (*see* **8.4**),
d) All dead and live loads coming over the spiral casing,
e) Loads transmitted through generator foundation (*see* IS 7207 : 1974),
f) Seismic forces, and
g) Forces transmitted from superstructure.

8.5.1 All protions of spiral casing should have sufficient concrete thickness to ensure water tightness and freedom from undesirable vibrations.

8.5.2 Design consists of determining concrete thickness and steel reinforcement at a few critical sections forming a workable pattern and checking for the worst possible combination of loading conditions.

8.6 Concreting of Spiral Casing

Concreting of spiral casing should be carried out in stages by making use of suitable construction joints and allowing sufficient time - lag between adjacent placements to allow for heat dissipation and minimizing the shrinkage effect. Proper water seals should be provided at the construction joint to avoid seepage. Attempt should be made to simultaneously concrete sections symmetrically placed about the centre line of spiral casing so as to reduce chances of shifting of the stay ring.

9 STEEL SPIRAL CASING

9.1 Types of Installation

The spiral casing in a unit with vertical setting is installed in any one of the following ways:

a) Embedded in concrete,
b) Embedded in concrete with an elastic packing between the spiral casing and the concrete on the upper half,

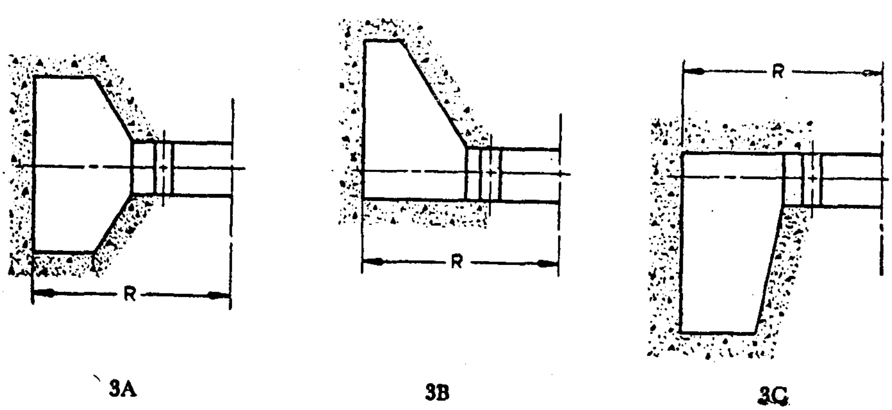

FIG. 3 TRAPEZOIDAL SHAPES OF SPIRAL CASING

c) Completely exposed and supported on spillar foundation, and
d) Half embedded in concrete.

9.2 Shape

Steel spiral casings are generally of circular or circular-cum-elliptical sections. They may be of cast or fabricated construction.

9.2.1 Depending upon the size, the spiral casings may be welded with the stay ring in the shop and divided in suitable number of parts to facilitate transportation to site. The joints may be either bolted or welded at site.

9.2.2 For large sizes, the spiral casings may be welded with the stay ring at site. The casing in such a case may be made in several segments of convenient sizes for transport facility. The segments should be strutted properly to prevent loss of shape during transit.

9.2.3 Part of the spiral casing near the tooth may be cast or fabricated alongwith the stay ring.

9.3 Material

Steel spiral casing may be made from cast steel (carbon and alloy), mild steel, boiler quality steel or high tensile alloy steel, conforming to IS 961 : 1975, IS 2002 : 1982, IS 2041 : 1982. High tensile alloy steel results in reducing the thickness of plate. If mild steel is used, the thickness of plate required should be more and rolling difficulties may arise.

9.4 Structural Design

The spiral casing should be designed for the maximum head including pressure rise due to water hammer in the casing.

9.4.1 Stress in spiral casing should be limited to the following values:

a) One-half the yield stress or one-third the ultimate stress, whichever is less, at maximum head including pressure rise due to water hammer in the casing; and
b) Eighty percent of the yield stress or 55 percent of ultimate stress, whichever is less, at hydraulic test pressure (*see* **9.5**).

9.4.2 For the purpose of design, the spiral casing may be divided into a number of sections and each section designed separately as a toroidal shell of uniform section identical to the given spiral casing section.

9.4.2.1 The maximum stresses occur at the junction of the spiral casing with the stay ring, where, in addition to tensile stresses, bending stresses also occur.

9.4.2.2 The junction may normally be strengthened by providing radial ribs or by using plates of higher strength material and/or of higher thickness for some distance from the point of junction.

9.4.2.3 The sections away from stay ring may be designed by the momentum theory for toroidal sections.

9.4.2.4 Corrosion allowance of 1 to 2 mm should be given,

9.5 Hydraulic Testing

The spiral casing should be tested at hydraulic test pressure, which is one and a half times the maximum pressure, including the pressure rise at sudden load throw-off, on the spiral casing. The duration of the test pressure should be of 30 minutes.

9.6 Stiffeners

In case of horizontal reaction turbines or where the spiral casing is not buried in concrete, suitable ribs may be provided at intervals to reduce the casing thickness and to make it rigid. The casing should also be provided with proper base plate to bolt it down.

9.7 Drainage

In case the spiral casing is designed in accordance with **8.1** (b) to **8.1** (d) suitable arrangement for internal drainage of water to take the following into account may be made arround the spiral casing for collecting any condensate and for draining out the same. The diameter of the perforated pipe should not be less than 200 mm and care should be taken that it does not get choked due to silt deposition.

9.8 Concreting Around Spiral Casing

9.8.1 Concrete around spiral casing should be designed for loads specified in **8.4** and **8.5** except that internal water pressure should not be considered in case where suitable precautions like provision of suitable compressible material, such as cork, tar mastic layer of proper thickness, etc, have been taken to ensure that this force is not transmitted to the concrete.

9.8.2 Precautions should be taken during concreting to avoid distortion of embedded

parts and shrinkage of concrete away from the bearing surfaces. The concrete should be laid carefully and evenly in shallow lifts at intervals to allow each lift to set before the next lift is placed.

10 MANHOLE

10.1 Manhole size should not be less than 600 mm diameter, where necessary, in the spiral casing to provide access to inspection, painting, repairs, etc.

ANNEX A

(*Clause* 2.1)

LIST OF REFERRED INDIAN STANDARDS

IS No.	*Title*
456 : 1978	Code of practice for plain and reinforced concrete (*third revision*)
961 : 1975	Structural steel (high tensile) (*second revision*)
1343 · 1980	Code of practicefor prestressed concrete (*first revision*)
2002 : 1982	Steel plates for pressure vessels for intermediate and high temperature service including boilers (*first revision*)
2041 : 1982	Steel plates for pressure vessels at moderate and low temperature (*first revision*)
2062 : 1984	Weldable structural steel (*third revision*)
3370	Code of practice for concrete structures for the storage of liquids
3370 (Part 1) : 1965	General requirements
3370 (Part 2) : 1965	Reinforced concrete structures
3370 (Part 3) : 1967	Prestressed concrete structures
3370 (Part 4) : 1967	Design tables

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